Planning for Earthquakes in the Wasatch Front

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by

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Executive Summary

This document addresses some of the strategies outlined in Objective 3 (Improve the Seismic Safety of Buildings and Infrastructure) of the *Strategic Plan for Earthquake Safety in Utah* (1995). Specifically this report investigates the problem of existing buildings in need of seismic retrofitting and the seismic vulnerability of future development in the Wasatch Front. It is divided into four parts that outline the problem, mitigation methods, existing policies, and recommendations for future action on the part of the Utah Seismic Safety Commission, the Utah State Legislature, and other state agencies.

Part 1 investigates the need for seismic safety planning along the Wasatch Front. The earthquake risk is significant. The potential damage of a major earthquake is examined in terms of the likelihood of an earthquake, geologic conditions that increase potential damage, existing and future land use, and the prevalence of highly vulnerable unreinforced masonry buildings. Part 1 also examines the reasons building owners decide to invest in retrofitting or ignore the problem, including awareness of an earthquake risk, cost, and whether the risk can be passed off to society.

Part 2 identifies different devices that may be used to promote retrofitting of seismically vulnerable buildings as well as land use planning techniques to mitigate the vulnerability of future development to earthquake damage. The effectiveness, feasibility, equity, and efficiency of these devices are examined. A successful program for retrofitting existing buildings must also include adequate incentives. In addition, adequate enforcement is crucial to many of the methods for retrofitting existing buildings and reviewing new development plans.

Part 3 examines state laws, policies, and programs that require or encourage the retrofitting of existing buildings. Efforts by municipalities, school districts, and other organizations are also discussed. Existing laws, policies and programs do not adequately address the problem. More steps must be taken to improve the seismic safety of existing buildings.

Part 4 contains recommendations to the Utah Seismic Safety Commission and the Utah State Legislature. Specific actions that will improve seismic safety are suggested. These include dedicated funding for seismic upgrades of state owned buildings, requirements for building owners to seismically strengthen their buildings, an inventory of seismically vulnerable buildings, incentives for building owners, and programs to increase public awareness.

Part 1: The Need for Seismic Safety Planning

The threat of a major earthquake along the Wasatch Front is one that cannot be ignored. Approximately 75% of Utah's 1.7 million people live within 15 miles of the Wasatch Fault's several segments (USGS 1995). Geologists have come up with many different estimates predicting the likelihood of an earthquake. They estimate that the probability of a major earthquake over the next 50 years is between 5 and 25 percent or more (USSC 2000). One study published in the *Journal of Geophysical Research* in 1996 stated that there is a 30 percent probability of a magnitude 7 or higher earthquake during the next century (Bauman 1999). A study by the Utah Geological Survey estimates that there is a 57 percent probability of a magnitude 7 earthquake along the Salt Lake segment of the Wasatch Fault during the next 100 years (Bauman 1999). The University of Utah Seismograph Stations estimates a 25 percent chance of a major earthquake in the next 50 years (UUSS).

Whatever the probability of a major earthquake, the assessment made by Grove Karl Gilbert of the U.S. Geological Survey in 1883 still holds true,

> "It is useless to ask when this disaster will occur. Our occupation of the country has been too brief for us to learn how fast the Wasatch grows; and indeed, it is only by such disasters that we can learn. By the time experience has taught us this, Salt Lake City will have been shaken down" (USGS 2000).

There is a long history of seismic activity in the Wasatch Front. The beautiful mountains that characterize the region are largely the result of seismic activity. Strong earthquakes have occurred about every 350 years for the past 6,000 years (USGS 1995), although the last quake with a magnitude of 7 or greater occurred about 600 years ago near Provo (Bauman 2001). Seismic activity is not restricted to the past. Every year an average of 500 mild earthquakes occur in the Wasatch Front region (UUSS).

The Wasatch Fault is what is called a normal fault or a dip slip fault (UUSS). When an earthquake occurs the fault slips in a vertical direction with the mountains rising relative to the valley floor (UUSS). During a magnitude 7.5 earthquake, vertical displacement of as much as 10 to 20 feet could occur (UUSS). The widest deformation tends to be on the down-dropped side of the fault (Berke and Beatley 1992). The zone of deformation created by a normal fault is asymmetrical and much wider than the deformation caused by a strike-slip fault, such as the San Andreas Fault (Berke and Beatley 1992).

Figure 1 shows the approximate locations of all earthquake faults in Utah. The Wasatch Fault is made up of several segments and encompasses the urban areas of Salt Lake, Provo and Ogden. A powerful earthquake could occur on each of these segments (USGS 1995). Considerable damage from strong ground shaking could occur up to 50 miles from the epicenter of the earthquake (UUSS). A powerful earthquake could result in soil liquefaction,

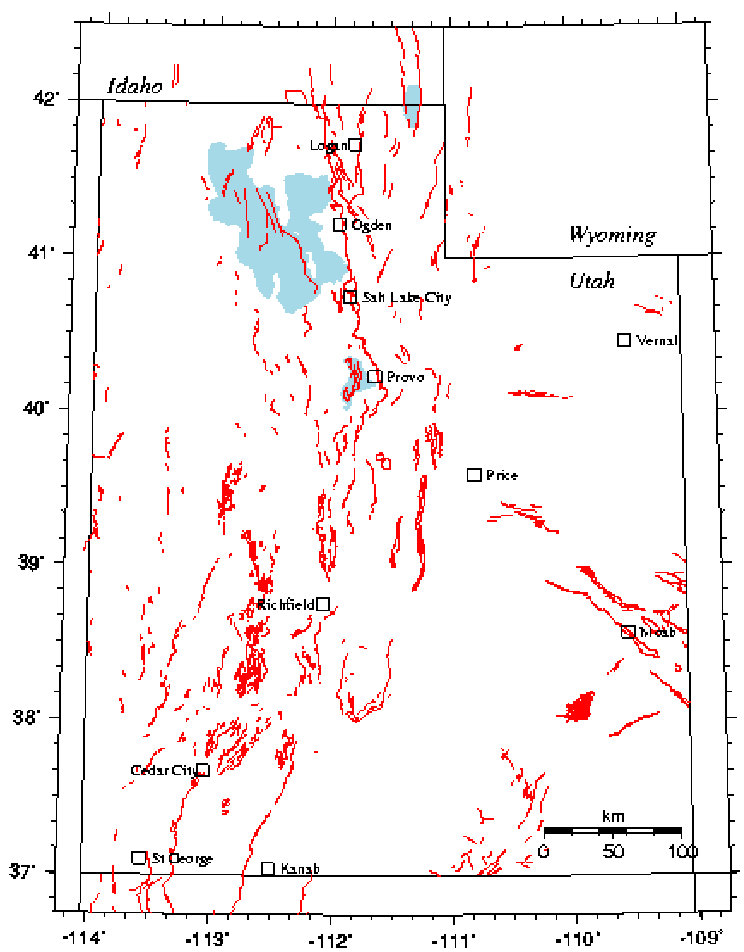

Figure 1: Utah Fault Map

landslides, and rock fall. Valley floors could also become permanently tilted, which could lead to significant flooding in urban areas from the Great Salt Lake and Utah Lake (UUSS).

The geology of the Wasatch Front further compounds the earthquake threat. The ancient Lake Bonneville covered much of the Wasatch Front region, which resulted in soft lake sediment being deposited on the valley floors. The urban areas of the Wasatch Front are built upon this soft lake sediment (USGS 1995). Of particular concern, given the geology of the area, are amplified ground shaking and also liquefaction, which is explained below.

The degree of ground shaking that occurs is not simply a result of the magnitude of an earthquake. An area underlain by soft lake sediment will experience greater surface effects than an area underlain by rock (Shedlock and Pakiser 1994). Kyle Rollins, a BYU geotechnical engineer, estimates that the ground shaking during a major earthquake in the Wasatch Front would be comparable to the ground shaking manifest on California's most vulnerable areas, such as the edge of the San Francisco Bay, which is underlain by soft fill (Siegel 1994). Ivan Wong reached a similar conclusion in a study for the Utah Geological Survey. He stated that a magnitude 7 earthquake in Salt Lake City could cause "one of the most severe instances of ground shaking ever experienced by a metropolitan area" in the United States (Siegel 1994).

Liquefaction can occur in an earthquake of magnitude 5 or greater where water saturated sandy soils exist (UGS 1997). When shaken, the ground liquefies and acts as a fluid (UGS 1997). This may significantly damage buildings by causing them to sink or tilt. Slope failures may also result. Liquefied soil on even gentle slopes may move.

Figure 2 shows the liquefaction potential in Salt Lake County (UGS 1994). During a 100-year period areas categorized as "high" in this map have a 50 percent probability of having an earthquake strong enough to cause liquefaction (UGS 1994). Much of the downtown area and the western part of Salt Lake City are highly vulnerable to liquefaction.

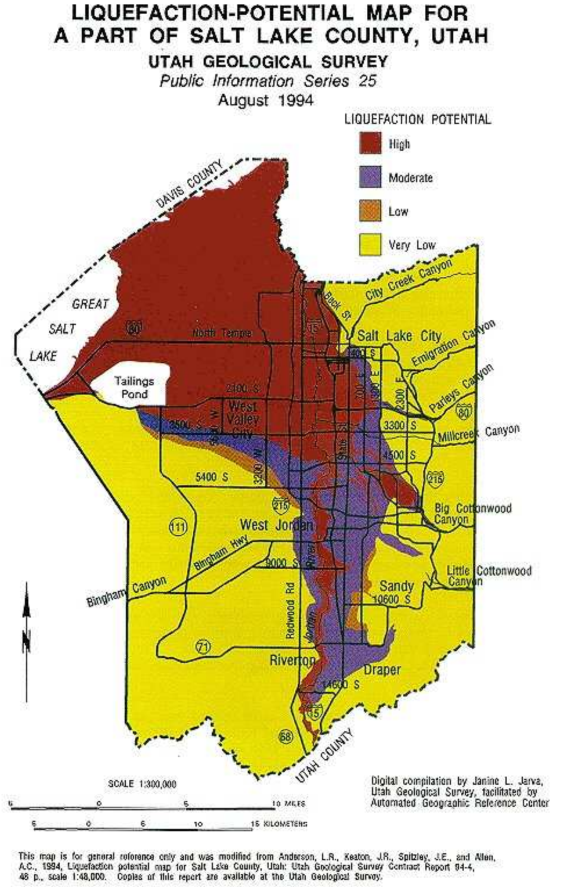

Figure 2: Salt Lake County Liquefaction Map

Land use in Salt Lake City makes its buildings even more susceptible to damage in a major earthquake. According to Kyle Rollins, "Salt Lake City is built exactly the wrong way given its geology… The taller structures in the downtown area are located on deep, soft soil deposits, which are most likely to cause damage to tall buildings. Many of the structures on stiff shallow sites on the edge of the basin are low-rise buildings, which are most vulnerable to the ground motions produced in stiff shallow soils" (Siegel 1994). In Salt Lake City, critical facilities such as hospitals, schools and high occupancy buildings have been located on or near fault traces (Berke and Beatley 1992). West Valley City conducted a seismic vulnerability assessment, which found that many critical facilities such as bridges, highway overpasses, power substations, water storage tanks, water lines, sewer lines and civil defense shelters needed retrofitting (Berke and Beatley 1992).

The casualties and financial cost resulting from a major earthquake along the Wasatch Front could be significant. Building damage alone in Salt Lake, Davis, and Utah counties in a magnitude 7.5 earthquake is estimated to cost $4.5 billion by the University of Utah Seismograph Stations (UUSS). This figure represents approximately 20 percent of the total economic loss that could occur (UUSS). A study by the Applied Technology Council estimates a magnitude 7.5 earthquake in Salt Lake County would cause direct losses of $9 billion to $15 billion (Bauman 1999). When indirect losses are taken into consideration, the cost increases to $11 billion to $18 billion (Bauman 1999). Federal estimates for the number of casualties that could occur in a magnitude 7.5 earthquake range from 2,300 to 24,000 people (Siegel 1994). Smaller earthquakes could also cause considerable damage. A magnitude 6.5 earthquake along the Wasatch Front could cause $2.3 billion in damage, while a magnitude 5.5 earthquake could cause $830 million in damage (UUSS).

In recent years the Wasatch Front has experienced rapid growth. This trend is projected to continue into the future. The 2000 census revealed that 80% of Utah's population or 1.7 million residents lived in the Wasatch Front (Envision Utah 2000). Envision Utah (2000) estimates that number will grow to 2.7 million residents by 2020 and to 5 million by 2050. If growth continues to occur in hazardous areas the estimates for loss of life and damage will only increase.

Many buildings in the Wasatch Front region were built before modern building codes were instituted. Prior to 1961 the Uniform Building Code did not incorporate design standards for seismic safety (UGS 1996). From 1961 to 1970 modest earthquake resistant design was incorporated into the Uniform Building Code (UGS 1996). Many of the buildings constructed prior to 1970 may be unsafe in an earthquake. Table 1 summarizes data from the 2000 Census displaying the number and percent of housing units built prior to 1960 and 1970 for counties in the Wasatch Front. If a significant number of these homes have not been reinforced to withstand earthquakes, the damage to housing could be significant in the event of an earthquake. These data do not differentiate between buildings constructed with unreinforced masonry and other building materials. Unreinforced masonry buildings are particularly vulnerable to damage because they do not have the structural strength to withstand the horizontal forces produced in earthquakes. In Salt Lake City approximately 30 percent of the homes are unreinforced masonry (Siegel 1996). For Salt Lake County the figure is slightly lower at 25 percent (Siegel 1996). In a major earthquake, 75 percent of building loss is expected to come from unreinforced masonry buildings (UUSS).

Table 1: Housing Built Prior to Incorporation of Seismic Standards in Building Code

	Total Housing Units	Housing Units Built Before 1960	Percent Housing Units Built Before 1960	Housing Units Built Before 1970	Percent Housing Units Built Before 1970
Box Elder County	14,209	5,243	37%	7,347	52%
Cache County	29,035	8,259	28%	11,281	39%
Davis County	74,114	12,599	17%	21,526	29%
Juab County	2,810	1,152	41%	1272	45%
Morgan County	2,158	576	27%	869	40%
Salt Lake County	310,988	86,756	28%	123,155	40%
Summit County	17,489	1,456	8%	2,267	13%
Tooele County	13,812	3,799	28%	5,255	38%
Utah County	104,315	22,484	22%	31,966	31%
Wasatch County	6,564	1,482	23%	1946	30%
Weber County	70,454	24,428	35%	33,415	47%

Unreinforced masonry buildings include historic buildings, schools, churches, government and commercial buildings as well as privately owned residences. To ensure safety during an earthquake, these buildings would have to be replaced or retrofitted to withstand earthquake forces. With such a large number of buildings at risk this is much easier said than done. The decision of an owner to retrofit an existing building is not always clear-cut.

Many different factors affect these decisions. They include experience with a prior earthquake, cost, building use, and whether the risk can be passed off to others. The Earthquake Engineering Research Institute sums up the dilemma that building owners face. “It is important to acknowledge that mitigation is not always the rational decision, given competing factors such as other risks, other investment opportunities, business issues, and the perceived level of risk” (EERI 1998).

Awareness and recognition of the seriousness of the issue are a major problem in motivating citizens and public officials to take action. Because no powerful earthquake has occurred in the Wasatch Front during the last 150 years, people do not take the future earthquake hazard as seriously as they should (USGS 1995). Previous experience with an earthquake greatly increases the likelihood of building owners investing in retrofitting their building (EERI 1998). M. Lee Allison, the director of the Utah Geological Survey, warned that, “Nothing will change unless a major landslide or earthquake kills people and causes huge economic losses, awakening landowners, developers and politicians to the threat of building on unsuitable sites” (Siegel 1999). This attitude is not a problem exclusive to the Wasatch Front. In California, where large earthquakes are more common, citizens and public officials are often in denial as to the seriousness of the issue.

“They see earthquakes simply as a normal and mostly uncontrollable background risk – the necessary tradeoff for a California lifestyle” (Beatley and Berke 1993).

Making the necessary repairs to ensure that a building is strong enough to withstand an earthquake is not inexpensive. For instance the Salt Lake School District spent an average of $833,333 retrofitting each of its school buildings for seismic safety (USSC 1995). If the state of Utah were to spend an average of $500,000 upgrading all school buildings in the state the total cost would amount to $300 million (USSC 1995). If money was made available to fund all of the retrofitting of school buildings in the state there would be $300 million less to spend on other worthy programs. The legislature must weigh the earthquake risks against other pressing social and economic needs. The choice is similar for other types of owners.

The use of a building may also indicate whether the owner will decide to retrofit the building. Public owners are often accountable to a wider segment of society than private owners (EERI 1998). The types of buildings they own may include schools, emergency facilities, hospitals, and government offices. It is also important that many of these buildings remain operational after an earthquake to assist in recovery. These unique responsibilities put more pressure on the government to ensure the safety of these buildings in the event of an earthquake. Similar circumstances may motivate nonprofit and private owners to retrofit their buildings. A company that does not want to lose market share following an earthquake may decide that retrofitting its building is worth the cost (EERI 1998).

If the risk associated with an unsafe building can be passed off to others, a building owner may not be motivated to do anything about the risk (EERI 1998). Risk can be passed to third parties or society through loan defaults, tax deductions of losses, and disaster assistance (EERI 1998). Programs that are intended to help victims following a disaster may actually deter a building owner from taking steps prior to an earthquake to prevent extensive damages.

In summary, the earthquake risk along the Wasatch Front should not be ignored. The likelihood of an earthquake, geologic conditions increasing risk, current land use and the prevalence of unreinforced masonry buildings all emphasize the importance of retrofitting existing buildings. There are many factors that contribute to building owners deciding not to retrofit. These factors include awareness of earthquake risk, cost, and whether the risk can be passes off to society.

Part 2: Policy Options for Improving Seismic Safety

There are many different approaches that state and local governments can take to improve mitigation of earthquake hazards. This section examines devices for improving the seismic safety of existing buildings and future development. The effectiveness, feasibility, equity, and efficiency of these devices are examined.

Existing Buildings

Devices used to improve the seismic safety of existing buildings include: building code triggers, mandatory strengthening, inventory of potentially hazardous buildings, notification of potential hazard, disclosure laws, requiring building owners to evaluate seismic risks, retrofit workshops, and simplified permit processes. Each of these devices has its advantages and disadvantages, which must be considered in deciding to use any particular device. For them to be successful, they must be enforced properly and used in conjunction with adequate incentives.

Building Code Triggers

Many communities use building code triggers to accomplish the goal of retrofitting unreinforced masonry buildings. For example, Seattle requires retrofitting whenever substantial remodeling is undertaken (Olshansky and Glick 1998). In San Diego, buildings that increase occupancy or change uses are required to be retrofitted (EERI 1998). Enforcement plays a big role in the effectiveness of triggers in decreasing earthquake risk. If knowledge of the law and enforcement are high, the efficiency of triggers is also high.

Mandatory Strengthening Programs

These programs require owners to strengthen unreinforced masonry buildings within a specified time period. This device has been effectively used in some communities in California. The California Seismic Safety Commission found that communities that have mandatory strengthening programs typically have much higher retrofit rates than other communities (2000). According to a 2000 survey 59% of unreinforced masonry buildings under mandatory programs in California had been either retrofitted or demolished (California Seismic Safety Commission 2000). Some of the communities that have adopted mandatory strengthening programs have yet to enforce these programs as evidenced by the absence of retrofit activity (California Seismic Safety Commission 2000). Another problem with mandatory strengthening programs is that they are associated with much higher demolition rates than voluntary strengthening programs (California Seismic Safety Commission 2000).

Examining the experiences of Los Angeles in administering a mandatory strengthening ordinance is useful in assessing the feasibility, equity and efficiency of these types of programs for possible use along the Wasatch Front. In 1981 Los Angeles adopted the Earthquake Hazard Reduction Ordinance that required nearly 8,000 buildings to be retrofitted, vacated, or demolished within 15 years (FEMA 1998). The program has been very successful in reducing the number of unreinforced masonry buildings. By 1996 one third of the buildings were vacated or demolished while approximately 95% of the remaining buildings were retrofitted (FEMA 1998). During the Northridge earthquake none of the URM buildings in Los Angeles collapsed (Olshansky 2001).

A study conduced by Cochrane (FEMA 1998) found that building owners were able to recoup the costs of retrofitting. The sale price for retrofitted buildings increased 37% (FEMA 1998). Many of these building provide low-income housing and the costs were often passed onto renters. After retrofitting, one third of the residential building owners applied for rent increases and were granted a 20% average increase (FEMA 1998). The number of demolitions also affected rental prices by reducing the supply of rental housing (FEMA 1998). San Francisco voters addressed the equity issue of increased rental prices by passing a $350 million bond for retrofitting loans; $150 million is being used for affordable housing while the remaining $200 million is being used to provide loans for other private retrofitting projects (EERI 1996).

Inventory of Potentially Hazardous Buildings

The State of California passed a law in 1986 that required all local governments within Seismic Zone 4 to compile inventories of all unreinforced masonry buildings in their jurisdictions (California Seismic Safety Commission 2000). An inventory of all potentially seismically unsafe buildings can be a worthwhile investment. The information gathered can be useful in defining the extent of the problems as well as developing an effective program. An inventory could show that a large number of essential buildings are at risk or that there are a large number of single-family homes that are at risk. Successful policies would probably be very different for these two situations. A building inventory allows a community to target its efforts where they are most needed. This device does not in and of itself reduce earthquake risk, but it is a very useful tool that improves the chances of success for other programs (Olshansky and Glick 1998).

The building inventory can also be used by local governments to notify building owners of their building's potential risk in an earthquake. Simply because building owners are aware of earthquake risk does not mean that they will be motivated to do anything about it. The California Seismic Safety Commission found that when there are economic incentives available to building owners they are much more likely to take action. In communities with voluntary programs and economic incentives, 36% of buildings were retrofitted, while only 11% of buildings in communities without economic incentives were retrofitted (California Seismic Safety Commission 2000).

Disclosure of Earthquake Hazards

The State of California requires that building owners notify the public about earthquake risk by posting a sign near the entrance stating, "This is an unreinforced masonry building. Ureinforced masonry buildings may be unsafe in the event of a major earthquake." (EERI 2001). The objective of this device is to motivate building owners to retrofit their buildings, but the California Seismic Safety Commission (2000) found that this method has not been effective in this regard.

Another type of notification device that is commonly used is requiring disclosure of earthquake risk when a building is sold. Whenever an unreinforced masonry building is sold in California the real estate agent must give a copy of the *Commercial Property Owner's Guide to Earthquake Safety* or *Homeowner's Guide to Earthquake Safety* to the buyer (EERI 2001). Other disclosure programs require that the buyer sign an earthquake risk disclosure document at the time of closing. Although the effectiveness of this device in reducing earthquake risk is unknown, buyers should be made aware of these risks for ethical reasons alone.

Disclosure and risk awareness appear to play a role in the market value of buildings. “The buyers in a seismically active area such as San Francisco are very aware of seismic upgrade issues, particularly associated with unreinforced masonry buildings. They will not pay the same price for an unreinforced building that they would pay for a strengthened building of the same caliber” (EERI 1998).

Require Building Owners to Evaluate Seismic Risks

Some California communities require that unreinforced masonry building owners evaluate the seismic risks of their buildings (California Seismic Safety Commission 2000). An engineering report under this law would detail what damage is likely in the event of an earthquake as well as necessary steps that must be taken to retrofit the building. Once again this method is only successful when it is accompanied by sufficient incentives.

Retrofit Workshops

Many communities have used retrofit workshops to motivate homeowners. San Leandro, California, conducts a particularly innovative workshop. At “Home Earthquake Strengthening Classes” homeowners receive guidance from experts, construction drawings with instructions, and building permit information (FEMA 1997). After participating in the workshop homeowners can borrow tools from the tool lending library (FEMA 1996). These tools were donated by the local Home Depot and other vendors (FEMA 1996). There is also a helpline that homeowners may call to get additional information (FEMA 1996). By 1997 this workshop was attended by 209 homeowners, and 75 homeowners received permits (FEMA 1997). Approximately $15,000 is spent annually on this program (FEMA 1997). This amount is modest when compared with the $500,000 spent in Seattle to educate homeowners about retrofitting (Rhodes 1998).

Simplified Permit Process

Local governments may choose to simplify their permit process to encourage retrofitting. In Seattle, homeowner permit applications for retrofitting are processed within 24 hours (Rhodes 1998). Berkeley completely waves permit fees for projects that include retrofitting (EERI 1998). Although this approach does not provide significant financial incentive to building owners to retrofit, it does make the process less cumbersome.

Evaluation of Devices for Existing Buildings

The effectiveness, feasibility, equity, and efficiency of prevalent devices are examined in the Table 2. Each device is ranked according to its effectiveness in accomplishing the goal of retrofitting unsafe buildings. Administrative feasibility is examined in terms of the amount of administrative oversight required by the government. A “low” designation indicates that the device would require significant staff time. Financial feasibility is examined from both the government’s and building owner’s

Table 2: Devices to Improve Seismic Safety of Existing Buildings

Device	Effectiveness		Feasibility Issues				Equity	Efficiency
	Rank	Keys to Success	Legal	Administrative	Financial Gov./Owner	Political		
Building code triggers	Med	§ Enforcement	Yes	Med	High/Low	Med	Med	Med
Mandatory strengthening	High	§ Enforcement § Incentives	Yes	Low	High/Low	Low	Low	Low
Inventory of potentially hazardous buildings	Low	§ Incentives	Yes	Med	Low/High	Med	High	Med
Notification of potential hazard to building owner	Med	§ Incentives	Yes	Med	Med/High	High	High	High
Notification posted on buildings	Low	§ Incentives	Yes	Med	High/High	Med	High	High
Disclosure of earthquake risk at the time of sale	Low	§ Timing	Yes	High	High/High	Med	High	Med
Require building owners to evaluate seismic risks	Med	§ Incentives	Yes	Low	High/Low	Low	Med	Med
Retrofit workshops	Med	§ Incentives	Yes	Med	Low/High	Med	Med	Med
Simplified permit process	Low		Yes	High	High	High	High	High

perspective. Due to the costs of retrofitting, the financial burden may be high for building owners.

The effectiveness of these devices depends on whether incentives are offered. Incentives are an essential part of any successful retrofitting program. If adequate incentives are not provided the program is almost sure to fail. The following is a list of different types of incentives that may be used to encourage retrofitting.

- Low interest loans
- Loan guarantees
- Bonds to fund loan programs
- Grants
- Reduced/waved permit fees
- Tax credits
- Tax abatement
- Tax increment financing
- Transfer tax rebate
- Property tax exclusion
- Technical assistance
- Reimbursement of engineering studies
- Density/intensity bonuses

Future Development

The extent to which future development is subject to seismic hazards can be reduced through the use of many different devices. These devises include building codes, geologic study requirements, zoning ordinances, subdivision ordinances, sensitive area ordinances, critical facilities permits, comprehensive plans, setbacks, disclosure laws, public awareness programs, and through land acquisition. Many land use planning techniques cost less than structural mitigation measures and can reduce earthquake loss in the long run (Bolton et al. 1986).

Building Codes

Building codes are the most effective means of ensuring the safety of future development according to seismic safety expert Olshansky (2001). There was minimal damage to newer buildings in Santa Cruz during the Loma Prieta Earthquake due largely to effective building codes (Schwab et al. 1998). Enforcement of building codes is particularly important in preventing damage. Local governments are usually responsible for enforcement of building codes. A survey of California building officials found that most do not consider seismic safety to be a high priority (Wyner and Mann 1986). This mind-set is particularly common in areas that have not recently experienced an earthquake (Wyner and Mann 1986). These attitudes toward seismic safety can translate into inadequate enforcement. Research has found that enforcement of building codes can vary widely among local governments in the same area (Burby, May and Paterson 1998). State governments can ensure that local building codes are properly enforced through training programs and monitoring.

Geologic Studies

A widely used approach for integrating seismic concerns in new development is through site specific geologic studies. A developer may be required to conduct a geologic study if the property lies within a special study zones or if the site characteristics, such as soils subject to liquefaction or steep slopes, trigger a geologic study. One example of a special study zone is California's Alquist-Priolo Special Studies Zones Act (State/Federal Hazard Mitigation Survey Team 1990). Active faults and fault zones were mapped by the California Division of Mines and Geology (State/Federal Hazard Mitigation Survey Team 1990). Most new development projects are required to conduct geologic studies if they fall within the mapped fault zones (State/Federal Hazard Mitigation Survey Team 1990). The requirements for geologic reports themselves can be very detailed or allow for flexibility by using performance standards (Berke and Beatley 1992). Outside review of geologic studies is also common.

Zoning Ordinances

A Zoning ordinance can reduce the amount of future development put at earthquake risk by regulating the location, use, and density of development. In high risk areas such as fault rupture zones the most appropriate use may be recreational uses or very low density residential rather than high density residential or industrial uses. It may not be feasible to prohibit development in all high risk areas, but a local government can certainly reduce the density of future development in these areas through zoning regulations (Berke and Beatley 1992). San Mateo County, California, takes a unique approach to dealing with seismic hazards in its zoning ordinance. The development density for land with active faults, slopes of 50% or greater, and areas susceptible to landslides is limited to one dwelling unit per 40 acres (Berke and Beatley 1992). This density reduction decreases the number of lives exposed to seismic risk.

Subdivision Ordinances

A Subdivision ordinance influences the layout of future development. A subdivision can be arranged to minimize exposure to seismic hazards to the greatest extent possible. A subdivision ordinance that allows for flexibility may be most effective at reducing seismic risks. For instance, high risk areas can be avoided through the clustering of development. The mapping of seismic hazards in site plans allows for these hazards to be considered during the subdivision review process. One example of this is the Portola Valley Ranch development, in which 205 homes were clustered on 43 acres of a 438 acre tract in order to avoid hazardous land. The remaining area was devoted to open space (Berke and Beatley 1992). The town of Portola Valley encourages this type of clustering in its zoning and development ordinances (Berke and Beatley 1992).

Devices such as density bonuses and transfer of development rights can be used to guide development away from hazardous areas. Clustering ordinances often contain density bonus provisions to encourage clustering (Berke and Beatley 1992). Density bonuses can be tied to the avoidance of seismic hazards (Berke and Beatley 1992). Transfer of development rights may be used to transfer development from a hazardous area to a more suitable area for development (Berke and Beatley 1992).

Sensitive Area Ordinances

Sensitive area ordinances address earthquake hazards along with a number of other environmental concerns. This approach makes sense because earthquakes can cause secondary hazards such as dam breach, liquefaction, debris flow, flooding, landslides, and rockfall. Limiting development in liquefaction areas or in close proximity to earthquake faults becomes even more important when the land is also subject to landslides. A mild earthquake could set in motion a landslide, particularly in developed areas that are prone to landslides (Bolton et al. 1986). It is also much easier to garner political support for earthquake hazard mitigation when it is linked to other high priority political issues (French et al. 1996). Sensitive area ordinances may use overlay zones to identify and implement policies such as performance standards and special studies and other requirements for these areas (Berke and Beatley 1992). Bellevue, Washington, uses a sensitive area overly to restrict land disturbance and density in steep slope areas (Berke and Beatley 1992).

Critical Facilities Permits

Critical facilities and uses are of special concern in earthquake planning. Critical facilities include power plants, hospitals, schools, fire stations, police stations, sewage treatment plants, and water tanks. These uses should be located in the safest possible areas and built to higher development standards. The Riverside County, California, comprehensive plan classifies areas of high or moderately high liquefaction potential as unsuitable for critical facilities (Berke and Beatley 1992). Belmont, California, does not permit critical uses in potential landslide areas, and on highly expansive soils, fill, and unconsolidated sediment they are permitted only if engineering solutions that reduce the risk of damage are possible (Berke and Beatley 1992).

Comprehensive Plans

A comprehensive plan is a potentially useful tool to mitigate earthquake hazards. A comprehensive plan provides a framework and policy context to guide the long term physical development of a jurisdiction. Comprehensive plans which address earthquake hazards give guidance to decision makers in adopting development ordinances and other policies that impact seismic safety. For instance a comprehensive plan may identify earthquake hazards such as faults and liquefaction, leaving the decisions on how to address these hazards to the public and private sector. Simply identifying hazards can make an impact on seismic safety. A study of the impact of land use plans in the Northridge Earthquake found that hazard identification in plans contributed to lower earthquake damages (French et al. 1996). The State of California requires that all city and county comprehensive plans include a safety element that addresses geological hazards (State/Federal Hazard Mitigation Survey Team 1990). This provision was adopted after the 1971 San Fernando earthquake (Berke and Beatley 1992). The seismic safety element typically specifies general policies and maps earthquake hazards (Berke and Beatley 1992).

Comprehensive plans have been criticized for because they are not extensively used by decision makers. After the Northridge Earthquake planners and engineers were asked about the usefulness of the seismic safety element of the comprehensive plan (SSC 1995). Overall they believed that the seismic safety element had been useful in mitigating earthquake hazards (SSC 1995). The seismic safety element provided leverage in mitigating hazards as well as educating planners and decision makers about earthquake hazards (SSC 1995). The effectiveness of the seismic safety element depended on the quality and accuracy of the information it provided. High quality, up to date plans were considered most effective in guiding decision makers (SSC 1995, Olshansky 2001).

Capital Facilities Plans and Public Investments

Earthquake hazard information can be incorporated into capital facilities plans and public investment decisions to reduce the amount of future development put at risk. The location of future urban development is influenced by public investments such as placement of roads and schools as well as the availability of water, sewer and other services (Berke and Beatley 1992). Public investments can be used strategically to guide development to certain areas and discourage development in areas with higher seismic risk (French et al. 1996).

Setbacks

Fault line setbacks are commonly used to protect future development from earthquakes. For all building intended for human occupancy California's Alquist-Priolo Special Studies Zone Act sets a minimum setback of 50 feet from mapped fault lines and fault traces (Berke and Beatley 1992). Portola Valley, California, instituted setback standards which are higher than those required by the state (Berke and Beatley 1992).

Earthquake resistant materials, such as wood frame houses, must be used in the area 50 to 125 feet away from the fault (Berke and Beatley 1992).

Although setback policies seem straightforward, in practice implementation has had its difficulties. Both Hayward and Santa Rosa, California, had difficulty implementing setback policies (Wyner and Mann 1986). The problems stemmed from the imprecise mapping of the Hayward and Healdsburg-Rodgers Creek faults (Wyner and Mann 1986). In mapped areas developers were required to trench or drill to find the exact location of the fault (Wyner and Mann 1986). Locating faults sometimes proves to be difficult and expensive (Wyner and Mann 1986). In some projects repeated trenching failed to find the location of the fault (Wyner and Mann 1986). The problem was compounded when the state geologist's office refused to revise boundaries (Wyner and Mann 1986). As technology for identifying and mapping faults improves implementing setback requirements will become easier.

Disclosure Laws

Real estate disclosure laws can be used to discourage development in hazardous areas. California's Natural Hazards Disclosure Act requires that prospective buyers be informed through a "Natural Hazard Disclosure Statement" if the property is located within a state mapped hazard area (California Geological Survey 2003). The purpose of real estate disclosure laws is to incorporate earthquake risk into the market. As discussed earlier, disclosure laws may not always affect individual's decisions but they do assist individuals in making informed choices and increase overall awareness of earthquake risks.

Public Awareness Programs

Programs to raise public awareness about the earthquake risk are an effective means of reducing damage levels during an earthquake. A study of land use planning for hazard mitigation conducted for the National Science Foundation found that there was a high correlation between public awareness components of land use plans and lower damage levels in the Northridge Earthquake (French et al. 1996). Public awareness programs also strengthen local commitment for earthquake hazard mitigation (French et al. 1996).

Acquisition

Acquisition of hazardous lands is one of the most effective forms of hazard mitigation. By purchasing hazardous land a municipality can ensure that private development will never occur on that land. The main drawback to land acquisition is the expense involved. Land acquisition becomes more practicable when combined with other community land acquisition programs, such as for open space (French et al. 1996). One example of this is land purchases of hazardous, steep slope land by the Midpenninsula Regional Open Space District in the San Francisco Bay Area (Berke and Beatley 1992). In this situation land was purchased for its recreational and scenic value, but it also served the purpose of keeping development out of a hazardous area (Berke and Beatley 1992). An alternative to outright acquisition of hazardous land is the acquisition of development rights. The advantage of this method is that it is less expensive to buy the development rights than the land itself (Berke and Beatley 1992). The town also won't have to pay for maintenance on the property since it remains in private hands and the land remains on the tax rolls as well (Berke and Beatley 1992).

Summary of Devices for Future Development

The effectiveness, feasibility, equity, and efficiency of devices which are used to reduce the vulnerability of future development are examined in Table 3. Each device is ranked according to its effectiveness in accomplishing the goal of reducing seismic risk of future development. Administrative feasibility is examined in terms of the amount of administrative oversight required by the government. A "low" designation indicates that the device would require significant staff time. Financial feasibility is examined from both the government's and building owner's perspective.

Table 3: Devices to Ensure Seismic Safety of Future Development

Device	Effectiveness		Feasibility Issues				Equity	Efficiency
	Rank	Keys to Success	Legal	Administrative	Financial Gov./Owner	Political		
Building code	High	§ Enforcement	Yes	High	High/Med	Med	Med	Med
Geologic studies triggers (Special study zones)	Med	§ Quality maps § Quality studies	Yes	Med	Med/Med	High	Med	Med
Zoning ordinance	Med	§ Information base § Incentives	Yes	High	High/High	Med	Med	High
Subdivision ordinance	Med	§ Information base § Incentives	Yes	High	Low/High	Med	High	Med
Sensitive area ordinances	Med	§ Information base	Yes	Med	Low/High	Med	Med	Med
Critical facilities permits	Med	§ Information base	Yes	High	High/Med	High	High	High
Setbacks	Med	§ Information base	Yes	High	High/Med	Med	High	High
Comprehensive plan	Low	§ Overall quality	Yes	Med	Med	High	Med	Med
Capital facilities and public investment policy	Low	§ Coordination	Yes	Med	Med	Med	Med	Med
Disclosure laws	Low	§ Timing	Yes	High	High/High	Med	High	Med
Land acquisition	High	§ Coordination	Yes	High	Low	Med	Med	Med

There are many different devices that local governments can use to protect future development from geologic hazards. Building codes have proven to be the most effective device, but there is certainly a role for other land use mitigation measures (Olshansky 2001). Site design which avoids seismic hazards can be encouraged in zoning ordinances, subdivision ordinances, critical facilities permits, sensitive area regulations, and through the use of geologic studies. Policies such as capital facility investments, disclosure of earthquake risks, and land acquisition can be used to steer development away from hazardous areas. The comprehensive plan can act as a policy guide for local governments and provide hazard information.

Part 3: Existing Policies

There are many different laws, policies, regulations and programs that address the problems of existing buildings that are in need of retrofitting for earthquake safety and the seismic safety of future development. There are 88 cities and towns, 10 counties, and numerous special service districts in the Wasatch Front region (Envision Utah 2000). Each of these has different laws and policies that address seismic safety.

Table 4 and 5 summarize the actions taken at the state and local level to reduce seismic risk for existing buildings and future development. Table 5 does not summarize provisions in the IBC but instead covers land use policies for future development (in addition to those that are addressed in the building code). Many municipalities leave the determination of fault setbacks to findings in site specific geologic studies. These municipalities were not counted as having minimum fault setbacks. A requirement to indicate hazards on subdivision plats was considered a type of disclosure law. Land acquisition for open space purposes, which also prevents development in hazardous areas, was counted. The information in these tables comes from interviews with planners, building officials, and engineers. Individuals were asked to answer questions to the best of their knowledge, but some may not have been aware of certain policies or may have interpreted the questions differently than intended.

Table 4: Summary of Policies for Existing Building

Entity	Adoption of the International Building Code	Adoption of the Parapet Ordinance	Adoption of the UCBC/Guidelines for Seismic Retrofit of Existing Buildings or Additional Retrofit Triggers	Real Estate Disclosure Laws for Existing Development	Consistent Funds for Seismic Retrofits	Funding Seismic Retrofits on a Project Basis	Inventory of all Potentially Hazardous State/City Buildings	Inventory of all Potentially Hazardous Buildings	Provide Incentives to Building Owners for Retrofitting
State of Utah	yes	yes	no	no	no	yes	yes	no	yes
Bluffdale	yes	yes	no	no	no	no	yes	no	no
Centerville	yes	yes	yes	no	no	no	no	no	no
Layton City	yes	no	no	no	no	yes	yes	no	no
Mapleton	yes	yes	no	yes	no	no	yes	no	no
Murray	yes	yes	no	no	no	no	yes	no	no
Orem	yes	yes	no	no	no	no	no	no	no
Provo City	yes	yes	no	no	no	no	yes	yes	no
Salt Lake City	yes	yes	no	no	yes	n/a	yes	no	yes
Salt Lake County	yes	yes	yes	no	no	yes	no	no	no
Salt Lake School District	n/a	n/a	n/a	n/a	yes	n/a	yes	n/a	n/a
The Church of Jesus Christ of Latter Day Saint	n/a	n/a	yes	n/a	yes	n/a	yes	n/a	n/a

Table 5: Summary of Policies for Future Development

Entity	Addressed in Comprehensive Plan	Zoning Ordinance	Subdivision Ordinance	Geologic Studies Triggers	Minimum Setbacks From Faults	Regulations that Address Liquefaction	Critical Facilities	Real Estate Disclosure Laws for Future Development	Capital Facilities/Public Investment Policy	Land Acquisition
State of Utah	no	no	no	no	no	no	no	no	no	no
Bluffdale	no	no	no	no	no	no	no	no	no	no
Bountiful	no	yes	no	no	no	no	no	no	no	no
Centerville	no	yes	no	yes	no	no	no	no	no	no
Eagle Mountain	no	no	no	yes	no	no	no	no	no	no
Layton City	yes	yes	no	yes	no	yes	no	yes	no	yes
Mapleton	yes	yes	yes	yes	yes	no	yes	yes	yes	no
Murray	yes	yes	yes	yes	no	no	no	no	no	no
Ogden City	yes	yes	yes	yes	yes	no	yes	yes	no	no
Orem	yes	no	yes	no	no	no	no	yes	no	yes
Provo City	yes	yes	no	yes	no	yes	no	yes	no	no
Salt Lake City	yes	no	yes	yes	yes	yes	yes	yes	no	yes
Salt Lake County	yes	yes	yes	yes	yes	yes	yes	yes	no	no
Weber County	yes	yes	no	yes	yes	no	yes	yes	no	no

This section details the laws, policies and actions taken at the state level to address the seismic safety of existing buildings and future development. Instances where local governments, school districts and other organization have taken greater steps than required by the state are also discussed. As shown in the preceding table the state of Utah has taken few significant steps to mitigate earthquake risks in comparison to local municipalities, school districts, and other organizations. The agencies highly involved at the state level include the Utah State Legislature, Utah Seismic Safety Commission (USSC), the Uniform Building Code Commission (UBCC), the Utah Geological Survey (UGS), the Utah Division of Comprehensive Emergency Management's Earthquake Preparedness Information Center (EPICenter), Envision Utah, Governors Office of Planning and Budget and the Utah Quality Growth Commission. Actions that contribute to and detract from seismic safety are examined.

The Utah political context must first be understood in order to appreciate the reasons behind state policies. Utah has been characterized as the most conservative state in the nation (Hrebenar et al. 1987). There is a strong tradition of local control over land use and development issues as well as an emphasis on the protection of individual property rights (Berke and Beatley 1992). This is illustrated in the legislature's enactment of the 1974 Utah Land Use Act, which required local land use planning and zoning (Mittler 1998). The act was so unpopular that it was revoked in a referendum with a vote of 242,068 to 157,438 (Mittler 1998).

Regional land use planning has been making strides in the last few years as growth has becomes an important issue along the Wasatch Front. In 1999 the Utah Quality Growth Commission was created with the passage of the Utah Quality Growth

Act. The commission’s duties include advising the legislature, administering a land conservation fund and awarding planning grants. Envision Utah, which was created in 1997, has taken a grass roots approach to address planning and growth issues in the Wasatch Front (Osborn 2001). Although not a state agency, Envision Utah aims to coordinate planning and development at the regional level (Osborn 2001). The American Planning Association awarded Envision Utah the Daniel Burnham Award for its efforts in regional planning (APA 2002).

The Utah Seismic Safety Commission has worked tirelessly in promoting seismic mitigation in the Wasatch Front but has been unsuccessful in effecting a major change in state policy. The commission was established in 1994 following the Northridge, California, earthquake to make recommendations to the state, local governments and other agencies (Mittler 1998). *A Strategic Plan for Earthquake Safety* was created by the Utah Seismic Safety Commission in 1995 (USSC 1995). This plan is a broad guide for mitigating seismic hazards coving issues such as improving the seismic safety of buildings, emergency response and recovery, education, and gathering hazard information (USSC 1995). In 1995 the USSC attempted to implement some of the strategies outlined in the plan by requesting funding for three programs that were aimed at education, reinforcing state buildings and updating earthquake monitoring equipment (Mittler 1998). The programs were ambitious. For example, a 25-year $10.5 million annual spending plan to make necessary retrofits to state buildings was requested (Mittler 1998). No money in the 1996 budget was allocated to any of these programs (Mittler 1998). The prediction by Janine Jarva, editor of the *Fault Line Forum*, that “Anything that costs money or creates new regulations is likely to meet resistance" proved true

(Mittler 1998). Although the creation of the USSC the previous year had been strongly supported in the legislature they appeared to be unwilling to take any significant steps toward mitigating seismic hazards (Mittler 1998).

Following the unsuccessful attempt in 1995 to procure state funding the USSC shifted its focus from advising the legislature to encouraging community support for seismic safety (Mittler 1998). The USSC efforts include sponsoring conferences such as "Earthquakes in Utah: Will Your Business Survive?," conducting surveys of companies and other groups, and promoting school earthquake preparedness (Mittler 1998, USSC 2000).

Seismic provisions in the building code are the most significant step to mitigate seismic hazards taken by the Utah Legislature. The Utah Uniform Building Code Commission adopted the International Building Code (IBC) and International Residential Code (IRC) in May of 2001 (IBC 2001). All local governments are required by the state to adopt the new code, which went into effect January 2002 (Earthquake Quarterly Spring 2001). Many other western states have not adopted the IBC, and some do not require local governments to adopt a building code. In 2000 the California Building Standards Commission (CBSC) voted not to adopt the IBC and instead continue using the 1997 Uniform Building Code (IBC 2000). This was a significant step back for a state that has long been a leader in the building code arena. Arizona, Idaho, Montana, New Mexico and Wyoming do not require the enforcement of seismic components of building codes (May et al. 1999).

Most of the provisions in the IBC pertain to new development. State law is somewhat confusing when it comes to retrofitting existing buildings. The state has not adopted a code such as the Uniform Code for Building Conservation (UCBC) for retrofitting existing buildings. Instead the UCBC as well as Guidelines for Seismic Retrofit of Exiting Buildings code are approved for use by local building inspectors, but not required (VonWeller 2003). This approach allows for flexibility on the part of local governments and building inspectors, but it precludes a standard statewide approach to existing buildings (VonWeller 2003).

State policy towards building codes over the past decade illustrates the difficulty in mitigating seismic risks at the state level. Prior to the creation of the IBC the State of Utah used the Uniform Building Code, which used seismic zones to set standards for development. In the past, there were debates concerning whether the seismic zone designations were appropriate for the earthquake conditions in the Wasatch Front. In the early 1990's the state considered changing the Uniform Building Code Seismic Zone from Zone 3 to Zone 4 along the Wasatch Front (VSP Associates 1993). Despite the strong scientific evidence in support of the change the legislature decided against it because of cost concerns raised by building owners and the development community (VSP Associates 1993). This entire debate over seismic zone designation became moot in January of 2002, with the adoption of the International Building Code 2000.

Many of the seismic safety provisions in the IBC are similar to the Uniform Building Code, while others are significantly different. The IBC uses ground acceleration maps rather than seismic zone designations (Marcum 2001). "Spectral Response Acceleration" maps are used to designate the stringency of standards a builder must comply with (Earthquake Quarterly Spring 2000). The IBC has a CD that specifies the spectral values for a given longitude and latitude (Earthquake Quarterly Spring 2000).

Steve Marcum, a structural engineer, explained its application to the Wasatch Front by stating that some areas in the valley would be held to standards similar to Zone 3 while those that could experience greater ground acceleration, such as along the benches, would be required to use more stringent standards similar to Zone 4 (Marcum 2001). The IBC does not apply to one and two family dwellings. They are covered by the IRC, which has less stringent seismic standards (Earthquake Quarterly Spring 2000).

The IBC contains a trigger requiring retrofitting of existing buildings when there is a change of use to a higher "seismic risk group" (Welliver 2003). An example of this would be when an office building is converted into a critical use, such as a fire station (Welliver 2003). The Utah State Legislature amended the code to require that when there is an occupancy increase of 100 percent or more the owner is required to retrofit the building (Welliver 2003). When there is a change of use or an increase in occupancy of less than 100 percent within the same seismic risk group the owner is not required to bring the building up to code (Welliver 2003).

A state amendment to the building code contains a provision, termed the "parapet ordinance" that addresses the seismic strengthening of existing buildings (USSC 1996). This ordinance requires that when unreinforced masonry buildings are reroofed that the roof is strengthened and tied to the walls (Siegel 2000). Also parapet walls, cornices, spires, towers, statuary and tanks must be reinforced (Siegel 2000). This ordinance applies only to commercial buildings. Approximately 30 percent of the housing stock in Salt Lake City is made up of unreinforced masonry homes, which are not required by law to be similarly reinforced when they are reroofed (Siegel 1996).

The parapet ordinance has not resulted in a significant improvement of the seismic safety of existing buildings since seismic strengthening is required only when a building is reroofed. There are many unsafe buildings that are not required to adhere to this ordinance. They may have been reroofed prior to this law coming into effect or are not currently in need of reroofing. Thus, it will take some time before all URM buildings are strengthened.

Enforcement is another problem with the parapet ordinance. A local municipality may be required to adhere to the building code, but it may not be aware of all of the code's provisions, or it may not consider some of the provisions a high priority and therefore not enforce them. After the Northridge earthquake, the California Seismic Safety Commission found that much of the damage could have been prevented if the building code had been strictly enforced (May et al. 1999). When interviewed by a local reporter, the chief building inspector of Provo, the second largest city in the Wasatch Front, stated that he was not aware of the parapet ordinance (Siegel 2000). This could be the case with many of the municipalities in the Wasatch Front. Some local governments do not require building permits for reroofing so they have no idea whether the law is being followed (Siegel 1999). Lack of awareness of the law does not necessarily mean an unwillingness to comply. When the Provo building inspector was informed of this law, he stated that he planned to now enforce it, especially in downtown where there is the most vulnerability (Siegel 2000).

Efforts are being made by two agencies to educate building inspectors, contractors and the public about the parapet ordinance. Informational brochures explaining the requirements of the parapet ordinance were created by the Earthquake Preparedness

Information Center (EPICenter) as well as the Utah Seismic Safety Commission (Carey 2000) (USSC 2000). The brochure produced by EPICenter was distributed to building owners, roofing contractors, engineers, and enforcement officials through mailings and conferences (Carey 2000). *Earthquakes and Roofing: What You Need to Know About Seismic Bracing When Reroofing Existing Buildings* published by the USSC in September 2000 is being used in a statewide educational campaign (USSC 2000).

Another publication by EPICenter, *The Utah Guide for the Seismic Improvement of Unreinforced Masonry Dwellings,* is being used for increasing homeowner awareness concerning unreinforced masonry homes. The publication provides information about unreinforced masonry homes and guidelines for seismically retrofitting them (USSC 2000).

Efforts have also been made to amend the building code to require that more existing buildings be retrofitted. At the Utah Seismic Safety Commission's request, the Uniform Building Code Commission (UBCC) was considering the adoption of a provision that would require the retrofitting of commercial buildings when they are remodeled for a new use (Siegel 1999). However, the UBCC was unable to adopt this provision when the assistant attorney general, Jeffery C. Hunt, informed the commission that adoption of this code would require an action by the legislature (Siegel 2000). The legislature has not subsequently taken steps to adopt this provision. Jim Bailey, structural engineer and member of Utah's Seismic Safety Commission, explained that the provision isn't particularly strict. "It's collapse prevention so people can get out and not be squashed… It's just criminal to not make them [building owners] fix that building so it's seismically safe." (Siegel 1999). As of 2000 the USSC and the UBCC were encouraging municipalities to adopt the code on their own (Siegel 2000).

Although not required to by law, many building owners choose to retrofit their buildings when purchasing a building or during remodeling. Financial institutions often require that buildings meet seismic codes before they will issue a loan. Building officials often act as advocates for seismic safety. Several building officials stated that although their city ordinances do not necessarily require building owners to retrofit their buildings when remodeling, they have been successful in convincing them to strengthen their buildings (VonWeller, Willright, Welliver 2003).

Real estate disclosure laws are not being used statewide to increase homebuyer awareness of earthquake risks. In Utah there is no law that requires the disclosure of geologic hazards to homebuyers (USSC 2000). There was an attempt in 1984 following severe landslides and floods in 1983 and the Borah Peak, Idaho earthquake to pass a bill in the state legislature that would "require that a buyer of property be informed of known geologic hazards that could affect that property" that failed (Mittler 1998). Salt Lake County is the only municipality in the Wasatch Front that requires the disclosure of earthquake risks during home sales (Siegel 1999). The Salt Lake County hazard disclosure provision applies to new development, where the severity of the hazard is recorded on the deed (Berke and Beatley 1992). Consideration was given to also applying the disclosure requirements to existing development, but this was decided against because of the objections of two elected officials who were concerned about significantly lowering property values and creating blighted areas (Berke and Beatley

1992). This policy fails to recognize the fact that the potential for loss of life is much greater in homes that were built before modern building codes were instituted.

The Utah Office of Historic Preservation provides incentives for retrofitting buildings (Siegel 1996). If retrofitting work exceeds $10,000 for a historic private or rental residence, the owner is eligible for the state historic preservation tax break (Siegel 1996). This includes an income tax credit for 20 percent of the rehabilitation costs (Siegel 1996). A similar federal tax credit is available for income producing properties (Siegel 1996).

State expenditures for retrofitting state owned buildings for seismic safety have not kept pace with the efforts of local municipalities, school districts, and other organizations in the Wasatch Front. The Division of Facilities Construction and Management surveyed 193 state-owned buildings, which were constructed before 1974, and found that 111 of them needed structural upgrading (USSC 2000). The USSC has been unsuccessful in obtaining dedicated state funding for addressing the seismic vulnerability of state owned buildings (USSC 2000). Instead, the legislature has opted to limit funding seismic strengthening to major remodeling projects (USSC 2000).

One high profile building that is in need of seismic strengthening is the 85-year-old State Capitol. The recent earthquake in Seattle and damage to the Washington State Capitol building brought this issue to the forefront. The Washington State Capitol was seismically strengthened in both 1965 and 1972 (Renzhofer 2001). Because of these retrofits the building survived the 6.8 magnitude earthquake with only minor damage. The Utah State Capitol is very similar in design and size to the Washington State Capitol (Renzhofer 2001). David Hart, executive director of the Capitol Preservation Board, explained the potential danger that the Utah State Capitol faces in the event of an earthquake.

> "If we had the same quake that was in Olympia we have estimated that the Capitol would have moved somewhere between 8 and 9 inches. That's enough to possibly cause the building to collapse on itself or demolish certain parts" (Speckman 2001).

The Capitol Preservation Board master plan to retrofit the Capitol also includes the construction of two additional buildings and refurbishing of the electrical system (Renzhofer 2001). The cost of this project is estimated to be $200 million, and the construction process is expected to take at least two decades (Renzhofer 2001). In March 2001 the Legislature approved $41 million to start the project (Speckman 2001). The reason the Utah State Capitol was not seismically strengthened sooner and why more steps aren't being taken by the legislature to retrofit state owned buildings can be summed up in the comments of David Hart, "The saddest part of the whole thing is we'll have spent all that money and no one will know we were in there" (Renzhofer 2001).

Salt Lake City has been more aggressive in funding retrofitting projects than the Utah state legislature. All of the city's vulnerable fire stations have been retrofitted (USSC 1996). Four of the six major hospital buildings have been replaced or seismically strengthened (USGS 1995). Base isolation was installed on the historic Salt Lake City and County Building, which is over 100 years old, to protect it from future earthquakes (USGS 1995).

The Salt Lake City Redevelopment Agency (RDA) provides incentives for residential and commercial building owners to retrofit their buildings (RDA 2003). The RDA provides low interest rate loans to building owners in the Central Business District to bring buildings up to code (RDA 2003). The RDA also sponsors a tax increment rebate program which provides tax rebates to residential and commercial property owners in certain redevelopment districts when they make a minimum of $10,000 investment in their property (RDA 2003). The RDA will rebate 100% of the tax increase resulting from increased property taxes due to an increase in the assessed value of the property (RDA 2003).

The Salt Lake School District has taken considerable actions to seismically upgrade all of its buildings. Efforts have been so significant that Steve Pratt, FEMA's earthquake manager for Region VIII, asserted that he knows of no other school district going to as much effort as the Salt Lake School District to ensure the safety of its students (Bauman 1999). The Salt Lake School District was the first school district in Utah to conduct a district-wide evaluation of its buildings (USSC 2000). Next the district created a plan to either retrofit or replace all vulnerable buildings based on the findings of the evaluation (USSC 2000). Work began in 1993 when voters approved a $70 million bond to retrofit all district schools by 2020 (Troomer-Cook 1998). The first priorities for upgrading were all three of Salt Lake's high schools (Bauman 1999). Much of the bond money was used to remodel and seismically strengthen these schools (Troomer-Cook 1998). In order to speed up the process in 1999 another bond of $136 million was passed by voters (Bauman 1999). What is particularly noteworthy of the Salt Lake City School District's efforts is that buildings were or will be retrofitted or rebuilt to higher standards than required by state law (Salt Lake City School District 2001). All schools have or will be upgraded to Seismic Zone 4 standards (Salt Lake City School District 2001).

The Salt Lake School District was spurred to action by the findings of a study conducted by Reavely Engineers and Associates in 1989 that found that 70 percent of

Salt Lake schools were poor or very poor in terms of seismic safety (Toomer-Cook 2002). The study estimated that approximately 3,000 students would die and another 7,700 would be injured if a 6.2 magnitude earthquake occurred during school hours (Toomer-Cook 2002).

Some of the school buildings require extensive work to be brought up to these stringent standards. One example of this is Franklin Elementary School. According to computer simulations the building would settle two or three inches and move up to eight feet horizontally in a moderate seismic event (Earthquake Quarterly Fall 1999). The Salt Lake School District spent $600,000 to inject 10,000 tons of stone beneath the building to strengthen the ground (Earthquake Quarterly Fall 1999). The upgrading, which included a seismic retrofitting, of West High School cost approximately $21.4 million (Cortez 1996). The project went about $5.7 million over budget after more structural problems were found, and the decision was made to install additional amenities (Cortez 1996).

The Salt Lake School District is not the only school district in the Wasatch Front region that is actively addressing the seismic safety of its buildings. Seismic safety has been evaluated for over 400 school buildings (USGS 1995). Morgan, Tooele, Beaver, Murray, Grand, Provo, Jordan, and Granite school districts have all either retrofitted or replaced seismically vulnerable buildings (USSC 1996).

There are many public schools still in need of retrofitting. Approximately 440 of Utah's schools were built before 1975 (Toomer-Cook 2002). Some school districts have plans to upgrade buildings, but it will take a significant amount of time before all upgrades will take place. For instance it will take Granite school district 45 years to upgrade all of their buildings (Toomer-Cook 2002). McKell Withers, assistant superintendent of support services in Granite District, stated "Look at the hundreds of millions of dollars legislators put into protecting the Capitol. It sure would be nice to have some of those dollars protecting kids" (Toomer-Cook 2002).

Another organization that has worked extensively to ensure the safety of its buildings is the Church of Jesus Christ of Latter-day Saints (LDS Church). One of the first major retrofitting projects undertaken in Salt Lake City was that of the Hotel Utah, a ten story structure built in the early 1900s. The hotel was being remodeled to accommodate offices and restaurants (EERI 1998). At the time state law did not require the building to be seismically strengthened. Approximately $4.5 million was spent on seismically upgrading the building (EERI 1998). This estimate is low because some of the costs of retrofitting were absorbed into the costs of remodeling (EERI 1998). Other historic buildings that the LDS Church has retrofitted include the Assembly Hall, the American Fork Tabernacle, and the Provo Tabernacle (USSC 1996).

The LDS Church policy requires the structural strengthening of buildings whenever they are remodeled or reroofed (Marcum 2001). The policy in 2001 was to strengthen buildings to higher standards than those required by state law (Marcum 2001). Rather than using the Utah Uniform Building Code for Building Upgrade, the LDS Church uses the latest documents from FEMA to guide evaluation and upgrade of buildings (Marcum 2001). Numerous meetinghouses and other buildings have been seismically strengthened according to this policy.

Agencies with responsibilities for critical facilities have also taken greater steps than required by state and local regulations. Utah Power conducts geotechnical studies that include liquefaction potential analysis for all its new building (USSC 1996).

Because of seismic concerns Mountain Fuel relocated critical company operations. The new facilities were built to seismic zone 4 standards (USSC 1996).

The Federal Government through FEMA has also helped to increase public awareness and preparation for possible disasters. FEMA has provided funding to several cities along the Wasatch Front as part of its Project Impact: Building a Disaster-Resistant Community program. Participating communities include: Salt Lake City, Centerville, Logan, and Provo (USSC 2000). These communities have received grants ranging from $150,000 to $500,000 to reduce hazard vulnerability (USSC 2000). Project Impact in Salt Lake City has been very successful in forming partnerships to make the community more resilient in the event of a disaster. James Lee Witt, FEMA Director, stated, "Salt Lake City is an excellent example of grassroots support, interested businesses and active government officials working to make risk reduction activities a reality" (*Earthquake Quarterly* Fall 1999).

In Utah authority for regulating land use is primarily at the local level. State agencies such as the Governors Office of Planning and Budget serve mainly as a resource for local governments and do not exercise authority over local land use planning. Local governments are not required by the state to prepare comprehensive plans or to address natural hazards in their land use policies (Christenson 2003).

The *Urban Planning Tools for Quality Growth*, a document created by Envision Utah with funding from the state, illustrates state policy in regards to land use planning for earthquakes. In the sensitive lands section, tools are discussed that can be used to mitigate the effects of natural disasters such as slope failures, floods and earthquakes.

However, the only tool for mitigating the effects of earthquakes that is mentioned is building codes.

> "The primary geologic hazard addressed in this workbook is slope failure or landslides. Earthquake hazards such as liquefaction and ground-shaking also exist, but because these events are geographically widespread, they typically are addressed through building code requirements that ensure structures are designed and retrofitted to withstand earthquakes" (Envision Utah 2000).

Because the effects of earthquakes are widespread does not necessarily mean that land use planning is not appropriate.

Although they are not required to by state law, most municipalities along the Wasatch Front have some type of natural hazards ordinance (Christenson 2003). The quality and enforcement of these ordinances varies widely (Christenson 2003). The cities with the strictest ordinances are typically the ones that have experienced the most natural hazard problems, chiefly landslides (Christenson 2003). The city of Layton is a good example of this. It has one of the strictest sensitive area ordinances because of the problems that it has had with landslides in the past (Christenson 2003). Most of the developments that are having problems were built in the late 1970s and early 1980s (Christenson 2003).

Among local governments in Utah, Salt Lake County is a leader in earthquake mitigation for future development using land use measures. It is the only county along the Wasatch Front that has a geologist on staff (Batatian 2003). The county has a long history of using land use controls to mitigate the effects of earthquakes. Salt Lake County began requiring geological site investigations for subdivision and zoning permits in 1965 for certain developments (Berke and Beatley 1992). In 1989 Salt Lake County adopted the Natural Hazards Ordinance, which requires proposed developments in hazard zones to conduct special engineering geology studies (Berke and Beatley 1992). Hazard zones are identified through liquefaction and fault rupture overlay maps (Berke and Beatley 1992). The ordinance allows for flexibility in mitigating hazards on each site. The Natural Hazards Ordinance prohibits construction of a building over an active fault but does not require setbacks from faults, limit certain land uses, or restrict density in hazard zones (Berke and Beatley 1992). The provisions of the Natural Hazards Ordinance apply to new development only (Berke and Beatley 1992). The Natural Hazards Ordinance also does not address the hazard of ground shaking, since that is addressed by the building codes (Berke and Beatley 1992).

The Natural Hazards Ordinance does not prohibit development in close proximity to fault lines (Berke and Beatley 1992). This policy is apparent in Salt Lake County where there has been significant development in close proximity to fault lines (Berke and Beatley 1992). There has actually been a demand for homes in these areas because of the striking views of the Salt Lake valley that exist on the upside of fault lines. As a result numerous expensive homes have been constructed in these areas (Berke and Beatley 1992).

Salt Lake County's Natural Hazards Ordinance, now the Geologic Hazards Ordinance, was revised in July 2002 to also include landslides, debris flow, and rock fall in addition to surface fault rupture, liquefaction and avalanche hazards (Salt Lake County 2002). There are several different geologic study triggers in the ordinance. These include lands identified in the Landslide, Debris Flow, and Rock Fall Special Study Area Map, Foothills and Canyons Overlay Zone, Surface Rupture and Liquefaction Potential Special Study Areas Map, slopes exceeding 30 percent, and other areas that indicate a potential for geologic hazards (Salt Lake County 2002). No critical facilities such as hospitals may be built in active fault areas and no structure for human occupancy may be built on a fault scarp (Salt Lake County 2002). One important new component of the Geologic Hazard Ordinance is the inclusion of a method for calculating fault setbacks. Previously there was no minimum setback from faults required or a method for deciding on appropriate setbacks. The setbacks are calculated based on the building use and the expected fault displacement (Salt Lake County 2002). The Utah Geological Survey plans to recommend that other local governments along the Wasatch Front adopt the setback requirements used by Salt Lake County (Batatian 2003).

Salt Lake City has not been as aggressive as Salt Lake County in its land use planning for earthquake hazard mitigation. Development surrounding active faults is the main focus of Salt Lake City's subdivision ordinance. Salt Lake City requires geological reports for subdivisions within 500 feet of a fault as well as setbacks from faults (Salt Lake City 1981). Salt Lake City has used other methods such as acquisition of hazardous properties to prevent development in hazardous areas. Salt Lake City acquired a particularly hazard prone area that was under development pressure and converted it into a public park (Berke and Beatley 1992). The acquisition and creation of Faultline Park not only prevented development of an apartment building in this area, but Faultline Park also serves as a public education purpose, by informing citizens about earthquake hazards in the area.

Mapleton City uses capital investment policies and the provision of public services to steer development from hazardous lands. In order to protect hillside areas Mapleton City made a conscious decision a number of years ago not to extend services such as water and sewer to hillside areas (Evans 2003). Mapleton City employs a transfer of development rights program (TDR) to transfer development from hillside areas to sites more suitable for development (Evans 2003). The TDR program is extensively used (Evans 2003). As a result, unlike many other Wasatch Front communities, there is not a lot of hillside development in Mapleton (Evans 2003).

Weber County's ordinance, termed "Natural Hazard Overlay Districts," is similar to Salt Lake County's Geologic Hazards Ordinance. Geologic studies are required in areas identified for liquefaction potential, landslide, rock fall/debris flow, and surface fault rupture (Weber County 2003). The only exception given is for residential areas located in potential liquefaction areas with less than 4 units per acre (Weber County 2003). Even though a special study is not required this information must still be recorded as a deed covenant running with the land (Weber County 2003).

Rather than having a specific geologic hazard ordinance many municipalities have sensitive land ordinances that incorporate geologic hazard mitigation. Layton and Ogden both take this approach. Layton City's ordinance classifies sensitive lands as those with: slope 10% or above, dam breach exposure, dense oak brush, fault zones, high liquefaction potential, debris flow and other sediment laden-flows, flooding, landslides, rock falls, shallow ground water, contaminated groundwater and wetlands (Layton 1997).

Ogden has incorporated earthquake hazard mitigation into its land use planning through the use of a sensitive area overlay zone (Montgomery 2003). The city has mapped active fault traces (Montgomery 2003). A geologic report must be conducted for any development within 1/8 of a mile from a fault (Montgomery 2003). The ordinance also stipulates minimum setbacks from faults. No buildings for human habitation may be built in the zone of deformation or within 50 feet of a fault (Montgomery 2003). Critical facilities, such as hospitals and power plants, must be at least 150 feet from a fault (Montgomery 2003).

Many municipalities require that geologic hazards be noted on subdivision plats. Layton, Mapleton, Ogden, Orem, Provo, Salt Lake City and Salt Lake County all require some disclosure of geologic hazards on subdivision plats. Disclosure ranges from showing actual fault lines on plats and delineating sensitive zones to noting that a geologic study was conducted for the site and where that study can be obtained. Provo City requires all geologic studies be referenced on the subdivision plat and that all faults and collapsible soils be shown (Graves 2003, Evans 2003). Orem also requires that known fault lines be shown (Stroud 2003). Ogden requires that mapped sensitive areas as defined in its ordinance be shown on subdivision plats (Snyder 2003).

The effectiveness of the all of these ordinances depends upon the accuracy of the maps. In 1997 Salt Lake County updated its geologic hazards map (USSC 2000). The new map initially left out the Warm Springs fault, a branch of the Wasatch fault, which travels directly through downtown Salt Lake City (USSC 2000). Several projects were approved, without conducting special engineering studies, before this discrepancy was discovered (USSC 2000).

The special engineering studies themselves have not been without controversy. In 1999 geologic features with tectonic characteristics were discovered during construction at the Salt Palace (USSC 2000). This discovery resulted in a highly politicized debate between geologists who disagreed whether the features were from a fault or simply from liquefaction-induced lateral spreading (USSC 2000). Salt Lake eventually accepted the theory that the geologic features were liquefaction-induced and allowed construction to continue (USSC 2000). The foundation was redesigned to withstand minor movement (USSC 2000). The Salt Palace eventually served as the media center for the 2002 Winter Olympic Games.

The quality of geologic reports can also vary widely. The Salt Lake County geologist, Darlene Batatian, was dismayed with the recommendations in the first geologic report that she reviewed (Batatian 2003). The report recommended only an eight foot fault setback for a three story 70,000 ft^2 office building (Batatian 2003). A larger setback was not possible given the size of the building and property (Batatian 2003). Although the office building was eventually built, the county geologist did succeed in requiring that the building be designed to stay together even if part of its foundation was lost in an earthquake (Batatian 2003). The Salt Lake County ordinance now requires minimum setbacks from faults (Batatian 2003). As shown in Table 5, many other municipalities have no minimum setback requirement and rely heavily on the recommendations in geologic studies (Batatian 2003).

An effort is being made by the Utah Geological Survey to encourage more local governments to incorporate earthquake hazard knowledge into land use planning. The Utah Geological Survey provides geologic hazard assistance to cities and towns including the preparation of ordinances, geologic hazard maps, and review of consultant's reports (UGS 2003). In 2001 the Utah Geological Survey published a report entitled: *Using Geologic-Hazard Information to Reduce Risks and Losses: A Guide for Local Governments*, which describes how local governments can incorporate geologic hazard information into land use regulations (UGS 2001). The Utah Geological Survey has published geologic hazard maps, which designate special study areas for areas surrounding surface fault ruptures, certain soil types, and other geologic features (UGS 2001). Local governments are encouraged to adopt geologic-hazards maps into their ordinances (UGS 2001). The information gained from the studies can be used to determine what action if any should be taken to address the earthquake hazard. This assistance makes it much easier for a local government to incorporate a geological study trigger into its ordinances.

The actions of school districts, local municipalities, and other organizations have been much more vigorous in addressing the earthquake vulnerability than those taken on the state level. There are not many incentives or requirements at the state level that increase the safety of existing buildings. On the one hand, school districts, local municipalities, and other organizations that are concerned about the safety of their buildings have typically retrofitted their buildings to much higher standards than those outlined in current codes. They have also been willing to provide the necessary funding for these large-scale projects. On the other hand, the state legislature has not set aside dedicated money for the seismic strengthening of state-owned buildings, let alone provided significant incentives to private building owners to retrofit their buildings. Existing laws, policies and programs do not adequately address the problem of seismically vulnerable buildings. Local governments have vastly different policies regarding the seismic safety of future development. Although the state has required all local governments to adopt and enforce the IBC, the state has not encouraged any other land use policies to protect future development in earthquake prone areas. More steps must be taken at the state level to improve the seismic safety of existing buildings and future development.

Part 4: Recommendations

Past efforts made by the Utah State Legislature have been inadequate in addressing the problem of the earthquake vulnerability of existing buildings. More should also be done by the state to protect future development from earthquake hazards. Effective mitigation of these risks will require a large departure from present policies. Efforts and funding should focus on the following programs: dedicated funding for seismic upgrades of state-owned buildings and public school buildings, an inventory of seismically vulnerable buildings, requirements and incentives for more building owners to seismically strengthen their buildings, workshops and other programs to increase public awareness, real estate disclosure laws, requirement for local governments to address seismic hazards in land use policies, and continuation of the Utah Geological Survey's planning assistance program.

At a minimum the state is responsible for the safety of the buildings which it owns. State-owned buildings are extremely vulnerable to a major earthquake. As noted earlier a recent survey found that of 193 state-owned buildings constructed before 1974, 111 are in need of structural upgrades (USSC 2000). This is a problem that can no longer be ignored. Although funding may not be available to retrofit all of these buildings in one year, at a minimum the state should set aside dedicated funding for seismic upgrades of state-owned buildings. The most vulnerable buildings should be retrofitted first.

More building owners should be required to strengthen their buildings. Triggers in the building code currently require the seismic strengthening of buildings only when they are reroofed or when occupancy increases by 100 percent. Too many school children would be put at risk during earthquakes because of the structural condition of many school buildings. All public school buildings should be required to meet the standards of the International Building Code. As discussed previously, the USSC has tried and failed to pass stricter building code triggers on the state level. This effort should not be abandoned. More pressure should be put on the legislature to adopt triggers that would require seismic strengthening when commercial buildings are remodeled, change use, or when there is any increase in occupancy. In order to be more politically and financially feasible these strengthening measures would not have to require retrofitting to current standards for all uses, but rather retrofitting to prevent collapse in the event of an earthquake. Buildings that are retrofitted in such a manner will most likely receive substantial damage in the event of an earthquake, but the strengthening should save lives.

An essential step to crafting successful retrofitting programs is an inventory of all seismically vulnerable buildings. The inventory should include government-owned buildings, commercial buildings, and residences. The extent of the problem can only be determined once there is concrete information available. Targeted programs could then be created based on this information. Programs could include any range of alternatives and incentives discussed in the previous sections. The inventory may also be very useful in garnering political support for reducing earthquake risk. Many municipalities and citizens are probably not aware of the extent of the problem. Even if nothing is done with this information before an earthquake, an inventory could still be very useful in disaster recovery. For all of these reasons a building inventory is a worthwhile investment.

Unreinforced masonry buildings make up 30 percent of Salt Lake City's residential housing stock (Siegel 1996). The damage caused by a major earthquake to residences in Salt Lake City alone could be substantial. There is not one good answer to adequately address this problem. The only sure way for the state to ensure that homes are strengthened is to condemn them all or to provide money for the retrofitting. Obviously these aren't politically or financially viable options.

Utah should require disclosure of potential geologic and structural hazards at the time of sale. Hazards should be recorded in the deed as well as on subdivision plats. Disclosure statements should be as specific as possible. For instance, if a home was built prior to 1970 and has not been retrofitted to withstand earthquakes, this fact should be disclosed to a potential homebuyer. Showing hazardous areas on subdivision plats not only assists planners in the review of the project, it also acts as a form of disclosure for potential homebuyers. Disclosure laws will also help to increase overall awareness of earthquake risks. Ethical reasons alone justify the use of real estate disclosure laws.

Workshops are a good way to inform and motivate homeowners without substantial investment. Methods similar to those used in workshops in San Leandro, California could be employed along the Wasatch Front. Existing publications that provide information about unreinforced masonry homes and guidelines for seismically retrofitting them such as *The Utah Guide for the Seismic Improvement of Unreinforced Masonry Dwellings* could be distributed at workshops.

Getting the word out about workshops and motivating homeowners to attend them is key to their success. Homeowners could be informed about the workshops through notifying neighborhood associations, community groups, church groups, and through the media. Another option would be to send information about workshops in the property tax bills of all homes constructed before 1970. Homeowners would be informed that their homes were constructed prior to the date when earthquake resilient design was incorporated into the building code. Therefore there is a good chance that their homes may be vulnerable during an earthquake. Homeowners would be much more likely to read information about their homes' earthquake risk if the notice accompanied their property tax bills rather than simply just a general mailing. Similar methods could be used to target private building owners.

Incentives for homeowners and private building owners are essential to increasing the number of buildings that are retrofitted. Insufficient funding is a major barrier for building owners to overcome when trying to retrofit their buildings. Building owners can find it difficult to obtain conventional loans for retrofitting (Theroux 1992). The Bellevue, Washington Project Impact partnered with local banks to provide special retrofit loans (City of Bellevue 1998). Other communities such as Los Angeles provide low interest loans to homeowners (Los Angeles Times 1998). Federal funds are used to write down the interest rates (Los Angeles Times 1998). These programs can make retrofitting more financially feasible for building owners.

Federal money may be available to help fund innovative retrofitting incentive programs. In Los Angeles a state and federally funded program selected 50 homes for free retrofitting to demonstrate that retrofitting saves money when compared with the damage that could occur during an earthquake (Orlov 2000). The $1.2 million in grants used to fund the program were obtained from FEMA, the U.S. Department of Housing and Urban Development, and the California Office of Emergency Services (Orlov 2000). Santa Cruz County implemented a program that reimbursed homeowners up to 50% of the cost of retrofitting their homes (FEMA 2003). The program cost $10,350,250

(FEMA 2003). FEMA funded $5,175,125 of this cost (FEMA 2003). FEMA estimates that this project will prevent more than $100 million in property damage and relocation costs following a major earthquake (FEMA 2003). These are just some examples of incentives that other communities have used to successfully motivate homeowners to retrofit.

Many local governments in Utah require geologic studies in certain areas, but do not necessarily restrict the density in these areas unless there are also concerns about preserving hillsides, landslides, debris flow, liquefaction, flooding, rockfall, etc. Research by Olshansky (2001), an expert in the field of land use planning for earthquakes, has shown that this approach is appropriate.

> "Seismic hazard information and seismic safety policies have generally not affected decisions on location, type or intensity of land uses, unless coupled with other concerns, such as protection of hillsides or river corridors. Nor is seismic safety raised by the public as a significant concern even in the largest and most controversial development projects. And, based on my related study of the effectiveness of seismic hazard maps in Los Angeles County, these are, in fact, appropriate responses to the information."

Unfortunately, all too often seismic hazards are taken out of the equation all together by some local governments. As shown in Table 3 several local governments only address seismic hazards through building codes. For instance, when asked about zoning or subdivision policies that address seismic hazards a planner from Bluffdale stated that "we are more concerned about wetlands" (Robison 2003). Certainly wetlands should be preserved, but their preservation shouldn't preclude adequately protecting future development from seismic hazards.

Local governments should be required by the state to address geologic hazards in their land use policy. This could be done through adding a safety element to the comprehensive plan, incorporating standards which address earthquakes into zoning or subdivision ordinances, or even through as stand alone policy document. This requirement need not add a significant financial burden. The Utah Geological Survey already has provided many local governments along the Wasatch Front with sensitive land maps and other planning assistance. The Utah Geological Survey program makes it possible for even a small local government without a lot of financial resources to address seismic hazards. A model hazards ordinance would also be helpful in incorporating seismic hazard information into local land use plans.

In Utah it is important that the state government takes the lead in earthquake hazard mitigation. Currently local governments along the Wasatch Front are exerting varying degrees of effort to plan for earthquakes. When a particular municipality works to mitigate losses, development may simply be shifted into a nearby municipality (French et al. 1996). This acts as a disincentive for local governments to take action (French et al. 1996). When a state mandates mitigation measures it puts all local governments on the same footing (French et al. 1996).

As discussed previously there are many reasons why more has not been done at the state level to mitigate the effects of future earthquakes. The Utah Seismic Safety Commission has taken the right approach in working to build political support for seismic safety issues. It should further draw upon the example of Envision Utah to garner more grass roots support. Efforts to enact *The Strategic Plan for Earthquake Safety in Utah* should also be continued.

Many of these proposals require substantial funding and may not be politically feasible in times of slow economic growth. The easy politically feasible options for mitigating earthquake risk have largely been taken. In *Earthquake Safety in Utah: A Progress Report on the Activities and Accomplishments of the Utah Seismic Safety Commission for the Period of July 1996 to June 2000* the USSC stated the following:

> "We've taken most of the easy steps towards earthquake preparedness that require only modest resources. There remains the challenge of taking key long-term defensive actions that will require larger funding in the range of hundreds of thousands to millions of dollars. The willingness of the public and private sectors in Utah to make such investments ought to be guided by sensible principles of risk management." (USSC 2000).

It is time for the legislature to take some of the more difficult steps towards earthquake hazard mitigation. The legislature has an obligation to provide funding to retrofit state-owned buildings. In order to ensure the safety of school children, all public school buildings should be brought up to code. More building owners should be required to strengthen their buildings when remodeling or changing uses. An inventory of all seismically vulnerable buildings is a worthwhile investment. It would provide the data state and local governments need to create targeted programs and incentives to address earthquake risk. Programs that increase public awareness and ability of the citizens to seismically strengthen their homes and privately owned buildings should be expanded. Local governments should be required to address seismic hazards in regulating future development. Significant damage to property and loss of life can be prevented by taking these steps before it is too late.

Glossary

Terms taken from:
The USGS Earthquake Glossary ***http://earthquake.usgs.gov/4kids/eqterms.html***
The California General Plan Glossary
http://www.cproundtable.org/cprwww/docs/glossary.html

Acceleration: When you step on the accelerator in the car or put on the brakes, the car goes faster or slower. When it is changing from one speed to another, it is accelerating (faster) or decelerating (slower). This change from one speed, or velocity, to another is called acceleration. During an earthquake when the ground is shaking, it also experiences acceleration. The peak acceleration is the largest acceleration recorded by a particular station during an earthquake.

Active fault: A fault that is likely to have another earthquake sometime in the future. Faults are commonly considered to be active if they have moved one or more times in the last 10,000 years.

Aftershocks: Earthquakes that follow the largest shock of an earthquake sequence. They are smaller than the mainshock and within 1-2 fault lengths distance from the mainshock fault. Aftershocks can continue over a period of weeks, months, or years. In general, the larger the mainshock, the larger and more numerous the aftershocks, and the longer they will continue.

Alluvium: Loose gravel, sand, silt, or clay deposited by streams.

Alquist-Priolo Special Studies Zone Act, Earthquake Fault Zone: A state designated seismic hazard zone along traces of potentially and recently active faults, in which specialized geologic investigations must be prepared prior to approval of certain types of new development.

Bedrock: Relatively hard, solid rock that commonly underlies softer rock, sediment, or soil; a subset of the basement.

Blind thrust fault: A thrust fault that does not rupture all the way up to the surface so there is no evidence of it on the ground. It is "buried" under the uppermost layers of rock in the crust.

Capital Facilities Plan: A program, administered by a city or county government which schedules permanent improvements, usually for a minimum of five years in the future, to fit the projected fiscal capability of the local jurisdiction.

Cluster Development: Development in which a number of dwelling units are placed in closer proximity than usual, or are attached, with the purpose of retaining an open space area.

Critical Facility: Facilities housing or serving many people, which are necessary in the event of an earthquake or flood, such as hospitals, fire, police, and emergency service facilities, utility "lifeline" facilities, such as water, electricity, and gas supply, sewage disposal, and communications and transportation facilities.

Comprehensive Plan: A compendium of city or county policies regarding its long-term development, in the form of maps and accompanying text. It may also be called a "City Plan," "General Plan," or "Master Plan."

Dip: The angle that a planar geologic surface (for example, a fault) is inclined from the horizontal.

Dip slip: See fault.

Displacement: The difference between the initial position of a reference point and any later position. The amount any point affected by an earthquake has moved from where it was before the earthquake.

Deformation: A change in the original shape of a material. When we are talking about earthquakes, deformation is due to stress and strain.

Density: The number of permanent residential dwelling units per acre of land.

Density Bonus: The allocation of development rights that allow a parcel to accommodate additional square footage or additional residential units beyond the maximum for which the parcel is zoned.

Earthquake: This term is used to describe both sudden slip on a fault, and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth.

Earthquake hazard: Anything associated with an earthquake that may affect the normal activities of people. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches.

Earthquake risk: The probable building damage, and number of people that are expected to be hurt or killed if a likely earthquake on a particular fault occurs. Earthquake risk and earthquake hazard are occasionally used interchangeably.

Epicenter: The point on the earth's surface vertically above the point in the crust where a seismic rupture begins.

Fault: A fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture. Strike-slip faults are vertical (or nearly vertical) fractures where the blocks have mostly moved horizontally. If the block opposite an observer looking across the fault moves to the right, the slip style is termed right lateral; if the block moves to the left, the motion is termed left lateral. Dip-slip faults are inclined fractures where the blocks have mostly shifted vertically. If the rock mass above an inclined fault moves down, the fault is termed normal, whereas if the rock above the fault moves up, the fault is termed reverse (or thrust). Oblique-slip faults have significant components of both slip styles.

Fault scarp: A feature on the surface of the earth that looks like a step caused by slip on the fault.

Fault trace: Intersection of a fault with the ground surface; also, the line commonly plotted on geologic maps to represent a fault.

Field Act: California legislation, passed after a 1933 Long Beach earthquake that collapsed a school that established more stringent structural requirements and standards for construction of schools than for other buildings.

Geologic Review: The analysis of geologic hazards, including all potential seismic hazards, surface ruptures, liquefaction, landsliding, mudsliding, and the potential for erosion and sedimentation.

Geotechnical: Referring to the use of scientific methods and engineering principles to acquire, interpret, and apply knowledge of earth materials for solving engineering problems.

Ground failure: A general reference to landslides, liquefaction, lateral spreads, and any other consequence of shaking that affects the stability of the ground.

Ground motion (shaking): The movement of the earth's surface from earthquakes or explosions. Ground motion is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the earth and along its surface.

Intensity: A number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. There are many intensities for an earthquake, depending on where you are, unlike the magnitude, which is one number for each earthquake.

Landslide: The downslope movement of soil and/or rock.

Lateral spread and flow: Terms referring to landslides that commonly form on gentle slopes and that have rapid fluid-like flow movement, like water.

Lifelines: Structures that are important or critical for a community to function, such as roadways, pipelines, powerlines, sewers, communications, and port facilities.

Liquefaction: A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like when you wiggle your toes in the wet sand near the water at the beach. This effect can be caused by earthquake shaking.

Mitigate: To ameliorate, alleviate, or avoid to the extent reasonably feasible.

Normal fault: (See fault.)

Overlay: A land use designation, or a zoning designation on a zoning map, that modifies the basic underlying designation in some specific manner.

Retrofit: To add materials and/or devices to an existing building or system to improve its operation, safety, or efficiency.

Safety Element: One of the seven California State-mandated elements of a local general plan, it contains adopted goals, policies, and implementation programs for the protection of the community from any unreasonable risks associated with seismic and geologic hazards, flooding, and wildland and urban fires.

Seiche: The sloshing of a closed body of water from earthquake shaking. Swimming pools often have seiches during earthquakes.

Seismic: Caused by or subject to earthquakes or earth vibrations.

Setback: The horizontal distance between the earthquake fault and any structure.

Slip: The relative displacement of formerly adjacent points on opposite sides of a fault, measured on the fault surface.

Soil: (1) In engineering, all unconsolidated material above bedrock. (2) In soil science, naturally occurring layers of mineral and (or) organic constituents that differ from the underlying parent material in their physical, chemical, mineralogical, and morphological character because of pedogenic processes (3) In other words, dirt.

Stick-slip: The fast movement that occurs between two sides of a fault when the two sides of the fault become unstuck. Stick-slip displacement on a fault radiates energy in the form of seismic waves, creating an earthquake.

Subdivision: The division of a tract of land into defined lots, either improved or unimproved, which can be separately conveyed by sale or lease, and which can be altered or developed.

Surface faulting: Displacement that reaches the earth's surface during slip along a fault. Commonly occurs with shallow earthquakes, those with an epicenter less than 20 km. Surface faulting also may accompany aseismic creep or natural or man-induced subsidence.

Transfer of Development Rights (TDR): A program that can relocate potential development from areas where proposed land use or environmental impacts are considered undesirable (the "donor" site) to another ("receiver") site chosen on the basis of its ability to accommodate additional units of development beyond that for which it was zoned, with minimal environmental, social, and aesthetic impacts.

Zoning: The division of a city or county by legislative regulations into areas, or zones, which specify allowable uses for real property and size restrictions for buildings within these areas.

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